

Prospective Clinical and Computed Tomography Evaluation of Calcaneus Fractures Treated Through Sinus Tarsi Approach

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Abstract

Background: The traditional lateral extensile approach to the calcaneus allows for excellent visualization but is associated with high wound complication rates. The sinus tarsi approach has been shown to produce similar radiographic outcomes with much lower rates of wound complications. The purpose of this study is to prospectively determine clinical and radiographic outcomes in calcaneus fractures treated with a sinus tarsi approach.

Methods: Twenty-nine patients with 30 calcaneus fractures underwent operative fixation through a sinus tarsi approach and were prospectively evaluated. Routine pre- and postoperative radiographs were obtained, in addition to computed tomography (CT) scans at 6 weeks and 12 months after surgery. Patient-reported outcomes including American Orthopaedic Foot & Ankle Society (AOFAS) score, visual analog scale (VAS) pain score, Veterans Rand 12-Item Health Survey (VR-12), and Foot Functional Index (FFI) were recorded. Patients were followed for a minimum of 1 year postoperation.

Results: Twenty-one patients with 22 calcaneus fractures completed 1 year of follow-up. At 12 months postoperation, 20 of 22 patients (91%) had 0 to 2 mm of fracture displacement at the posterior facet on CT scans whereas 2 of 22 patients had 2 to 4 mm of fracture displacement. There was no significant change in posterior facet fracture displacement comparing 6-week and 12-month postoperative CT scans ($P > .99$). Mean postoperative Bohler angle was 26.1 degrees compared to 13.2 degrees preoperatively. All patients had complete union of fracture site. There were no major wound complications. Four of 22 patients (18.2%) had minor wound complications. AOFAS, FFI, and VAS pain scores improved postoperatively but were not found to correlate with Bohler angle or critical angle of Gissane.

Conclusion: We found that in select patients excellent anatomic alignment and good clinical outcomes with low wound complication rates can be achieved when fixing calcaneus fractures through the sinus tarsi approach.

Level of Evidence: Level II, prospective cohort study.

Keywords: calcaneus fracture, limited incision, sinus tarsi approach, CT scan

Introduction

Calcaneus fractures are devastating injuries with potential complications that may include persistent pain, malunion, sural neuritis, and posttraumatic arthritis.²¹ Patients who have sustained a calcaneus fracture have a lower quality of life and higher rates of disability.⁴ These fractures also have a substantial socioeconomic impact, with just over 50% of patients returning to the same occupation after the injury.⁸

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Oftentimes, these injuries are best treated with anatomic reduction and fixation via open techniques. The traditional approach to calcaneus fracture fixation with a lateral extensile incision provides visualization of the entire body of the fractured calcaneus including the posterior facet of the subtalar joint and the anterior process of the calcaneus. However, this approach is associated with wound complications in as high as 32% of cases.² Modern techniques using a sinus tarsi approach have proven to produce similar clinical and radiographic results with much lower rates of wound complications and shorter operative times.^{6,19,23,26}

The purpose of this study was to prospectively evaluate radiographic and clinical outcomes, computed tomography (CT) scans at 6 weeks and 1 year postoperation, and patient-reported outcomes from a series of patients treated with a sinus tarsi approach for calcaneus fracture fixation.

Materials and Methods

After approval from our institutional review board, 29 patients with 30 calcaneus fractures were prospectively enrolled and underwent operative fixation with a low-profile anatomically designed plating system (Acumed, Portland, OR) through a sinus tarsi approach. All surgeries were performed by 1 of 7 fellowship-trained orthopaedic surgeons. Patients were included if they sustained a closed Sanders type II or III calcaneus fracture. Patients were excluded if they were less than 18 years of age, sustained an open or Sanders type I or IV calcaneus fracture, were currently pregnant or planning to become pregnant in the next 12 months, lacked a preoperative CT scan, underwent extensile lateral approach, underwent fixation with constructs other than a calcaneus plate, or underwent concomitant foot and/or ankle procedure including subtalar arthrodesis.

Preoperative foot (anteroposterior, lateral and oblique) and axial calcaneus radiographs and a CT scan were obtained for all patients. Patients were then seen in clinic at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months postoperatively. Radiographs (foot anteroposterior, lateral, oblique, and axial calcaneus) were obtained at each visit other than the 2-week postoperative visit. A CT scan was obtained at 6 weeks and 12 months postoperation to evaluate fracture alignment in the context of this investigation as it is not our typical practice to obtain postoperative CT scans. Patient questionnaires were completed preoperatively and at the 6- and 12-month postoperative visits.

The primary outcome variable was fracture alignment at final follow-up based on 1-year postoperative CT scans and radiographs. Radiographic measurements were performed by 2 authors who were not involved in the initial operative fixation. Alignment was defined as the amount of displacement, in millimeters, of the subtalar joint posterior facet in the coronal plane on CT scan. Secondary outcome

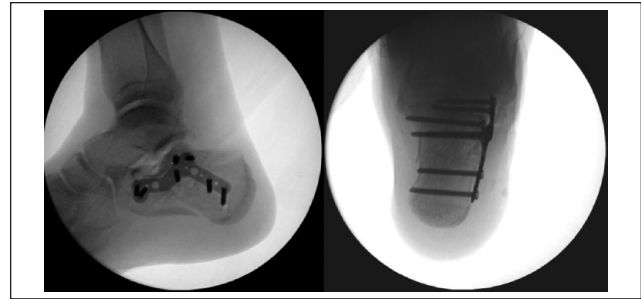


Figure 1. Intraoperative fluoroscopy of low-profile anatomically designed calcaneus plate.

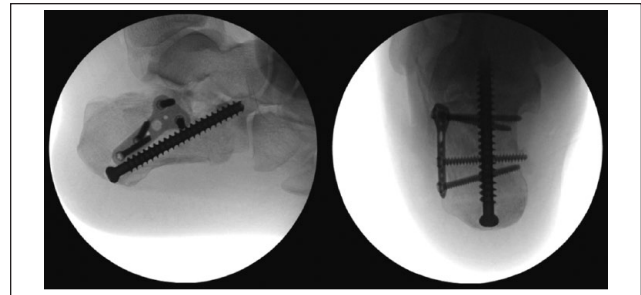


Figure 2. Intraoperative fluoroscopy of low-profile anatomically designed calcaneus plate.

variables included Bohler angle, Gissane angle, presence of subtalar joint arthritis, as well as patient-reported outcomes including American Orthopaedic Foot & Ankle Society (AOFAS) score, visual analog scale (VAS) pain score, Veterans Rand 12-Item Health Survey (VR-12), and Foot Functional Index (FFI). Subtalar joint arthritis was graded using the Kellgren and Lawrence Grading System, which ranges from 0 (no radiographic findings of osteoarthritis) to 4 (osteophytes and severe joint space narrowing and subchondral sclerosis).¹⁷

Surgical Technique

A sinus tarsi approach to the calcaneus was performed as previously described.¹⁹ In brief, a 2- to 4-cm incision was made from the tip of the fibula to the base of the fourth metatarsal. The extensor digitorum brevis was split or retracted, allowing exposure of the sinus tarsi and visualization of the subtalar joint posterior facet. A Schanz pin was placed into the calcaneal tuberosity from lateral to medial to provide manipulation of the tuberosity fragment. The posterior facet was reduced with small elevators and the angle of Gissane was restored. Small Kirschner wires were used for provisional fixation and small fragment screws were often placed in lag fashion under the posterior facet. A plate of appropriate size and configuration was selected based on the fracture pattern (Figures 1 and 2). The plate was secured

Table 1. Summary of Demographics for 22 Patients With 12-Month Follow-up.

Demographic	Number of Patients (n=22)
Age, y, mean \pm SD	53 \pm 11.7
BMI, mean \pm SD	27 \pm 5.1
Male sex, n (%)	15 (68)
Tobacco use, n (%)	
Current	7 (32)
Former	7 (32)
Worker's compensation, n (%)	1 (4.5)

Abbreviation: BMI, body mass index.

with screws and the incision was closed in a layered fashion. Postoperatively, patients were placed into a well-padded splint. At 2 weeks postoperation, patients were placed into a boot and range of motion exercises were permitted and encouraged. Weightbearing in the boot was initiated 8 weeks after surgery. Patients transitioned out of the boot into regular shoe wear at 12 weeks postoperatively.

Statistical Evaluation

Statistical analyses were performed to determine the differences between the 2 groups for each variable. Student *t* test and Pearson correlation coefficient were used in the analysis. An alpha level of 0.05 was used for all statistical tests.

Results

A total of 215 fractures were initially identified. Sixty-eight fractures were excluded because of simultaneous subtalar arthrodesis procedure. The remaining 117 were excluded either because of the aforementioned exclusion criteria or failure of primary surgeon to initiate enrollment in the study. Twenty-nine patients with a total of 30 fractures underwent operative fixation with a low-profile anatomically designed calcaneus plating system through a sinus tarsi approach between August 2014 and November 2018. Twenty-one patients with 22 fractures completed 12 months of follow-up. Demographic data are summarized in Table 1. Our patient population was majority male with average age of 53 years and average body mass index (BMI) of 27. Fifteen fractures were Sanders type II and 7 were Sanders III classification. One patient was a worker's compensation case. Seven of 22 patients (32%) were smokers (tobacco), one patient had idiopathic neuropathy of their bilateral lower extremities. Time from injury to surgery ranged from 1 day to 23 days, with an average time to surgery of 11 days. No patients underwent temporizing procedures prior to definitive fixation such as percutaneous pinning or external fixator.

At 12 months postoperation, 20 of 22 patients (91%) had 0 to 2 mm of fracture displacement at the posterior



Figure 3. Coronal CT scan at 12 months postoperatively demonstrating (A) 0- to 2-mm fracture displacement in one patient and (B) 2- to 4-mm fracture displacement in another patient.

facet based on CT scan, whereas 2 of 22 patients (9.1%) had 2 to 4 mm of fracture displacement (Figure 3). The mean Bohler angle at 12 months postoperative was 26.1 degrees and the mean critical angle of Gissane was 111.8 degrees, compared with a preoperative Bohler angle of 13.2 degrees and preoperative critical angle of Gissane of 109.1 degrees. The mean grade of subtalar arthritis based on the Kellgren and Lawrence grading system was 2.1. By 12 months postoperation, all patients had complete union of their fracture site. When comparing CT scans obtained at 6 weeks and 12 months postoperatively, there were no significant changes in radiographic measurements of fracture reduction including Bohler angle ($P=.48$), angle of Gissane ($P=.58$), and fracture displacement at posterior facet ($P>.99$). The mean total AOFAS score was 80.2, the mean physical and mental component scores of the VR-12 were 47.1 and 54.3, respectively, the mean total FFI score was 15.5, and the mean VAS activity and end-of-day scores were 2.6 and 2.8, respectively. Mean values of all radiographic outcome measures over time are summarized in Table 2.

Bohler angle, critical angle of Gissane, and grade of subtalar arthritis were not found to correlate with total AOFAS and total FFI scores at 12 months postoperation (Table 3). The total AOFAS score improved from 69.8 at 3 months postoperation to 80.2 at 12 months postoperation ($P=.018$). Figure 4 illustrates the changes in patient-reported outcomes over time.

Complication data are summarized in Table 4. There were no major wound complications (defined as requiring reoperation). Four of 22 patients (18.2%) had minor wound complications: 1 superficial wound necrosis, 2 superficial wound dehiscence, and 1 superficial surgical site infection. Two of 22 patients (9.1%) underwent reoperation for removal of symptomatic hardware. One patient (4.5%) underwent subtalar fusion at 1 year postoperation.

Table 2. Radiographic Outcome Measures.

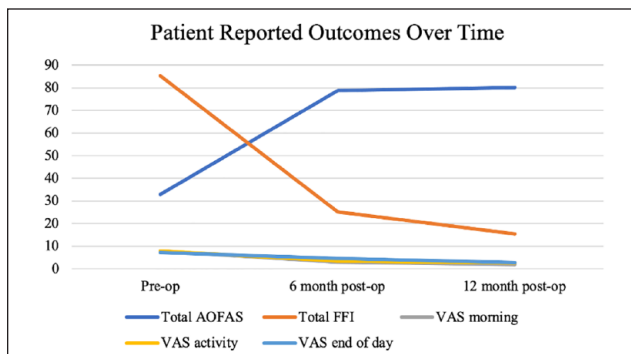
	6 wk	12 wk	6 mo	12 mo
Bohler angle, degrees, mean \pm SD	28.3 \pm 9.0	27 \pm 9.6	27.5 \pm 9.3	26.1 \pm 8.9
Angle of Gissane, degrees, mean \pm SD	110.1 \pm 8.0	110 \pm 8.0	111.2 \pm 7.7	111.8 \pm 6.3
Fracture displacement at posterior facet, ^a n (%)				
0-2 mm	21 (95.5)	–	–	20 (90.9)
2-4 mm	1 (4.5)	–	–	2 (9.1%)

^aComputed tomographic scans obtained at 6 weeks and 12 months postoperatively.

Table 3. Correlation Between Radiographic Parameters and Patient-Reported Outcomes at 12 Months Postoperation.

	Pearson Correlation Coefficient (<i>P</i> value)	
	Total AOFAS Score	Total FFI Score
Bohler angle	0.27 (<i>P</i> = .21)	–0.25 (<i>P</i> = .26)
Critical angle of Gissane	0.23 (<i>P</i> = .28)	–0.18 (<i>P</i> = .42)
Subtalar arthritis ^a	–0.12 (<i>P</i> = .58)	0.18 (<i>P</i> = .42)

^aSubtalar arthritis grade based on the Kellgren and Lawrence grading system.

**Figure 4.** Patient-reported outcomes over time.**Table 4.** Complications for 22 Patients With 12-Month Follow-up.

Complication	n (%)
Wound necrosis	1 (4.5)
Wound dehiscence	2 (9.1)
Superficial infection	1 (4.5)
Deep infection	0 (0)
Reoperation	
Hardware removal	2 (9.1)
Subtalar fusion	1 (4.5)

There were no differences in total AOFAS and total FFI scores at 12 months postoperation based on gender, but women were found to have significantly higher VAS pain

scores in the morning (*P* = .04), with activity (*P* = .006) and at the end of the day (*P* = .03). Patients with a history of tobacco use had no differences in total AOFAS, total FFI, and VAS pain scores when compared to patients who denied tobacco use. Higher BMI and morning VAS scores had a statistically significant negative linear relationship (*P* = .01), but no correlation was seen between BMI and total AOFAS, total FFI, VAS pain with activity, and VAS pain at end of the day scores.

Discussion

The sinus tarsi approach for management of intraarticular calcaneus fractures has gained popularity largely based on lower wound complication rates. The quality of the reduction has not been as extensively reviewed. This study presents a prospective series of 22 surgically treated calcaneus fractures using this approach. Anatomic reduction with step-off at the posterior facet less than 2 mm was achieved in all but 2 patients. The posterior facet step-off for these 2 patients was less than 4 mm. Furthermore, in our cohort, Bohler angle was restored to a mean angle of 26.1 degrees at final follow-up and was maintained between 6 weeks and 12 months postoperation. The critical angle of Gissane and fracture displacement at posterior facet were also maintained when comparing 6-week postoperative and 12-month postoperative CT scans. These results are in concordance with similar reports of surgically managed calcaneus fractures through the sinus tarsi approach.^{11,15,18,22,24,27} Recently, however, Busel et al⁹ found that Sanders type III calcaneus fractures trended toward better reduction quality with use of the extensile lateral rather than a sinus tarsi approach.

To our knowledge, this prospective study is the first to evaluate both radiographic and patient-reported outcomes after plate fixation of calcaneus fractures through the sinus tarsi approach. Scott et al²⁴ retrospectively examined plate fixation of calcaneus fractures through the sinus tarsi approach but did not evaluate functional or patient-reported outcomes. In addition, our cohort underwent CT scans preoperatively and at 6 weeks and 12 months postoperatively, allowing us to scrutinize the quality of the posterior facet reduction, and its durability over time.

In calcaneus fractures treated either operatively or non-operatively, incongruity of the posterior facet on CT scan and decreased Bohler angle are more commonly associated with poor clinical outcomes.¹⁶ After a displaced intraarticular calcaneus fracture, initial nonoperative management, worker's compensation status, Sanders type IV classification, and Bohler angle less than 0 degrees are predictors of future subtalar fusion for treatment of pain and poor function.¹⁰ Furthermore, after fixation of closed intraarticular calcaneus fractures, Bohler angle is correlated with functional recovery.²⁵ Interestingly, our study did not find a correlation between Bohler angle and total AOFAS or total FFI scores at 12 months postoperatively.

The extensile lateral approach to the calcaneus allows for good visualization when performing open reduction internal fixation; however, major wound complications after this approach range from 11% to 32%.^{2,3,5,13,14} Limited incision approaches to the calcaneus, including the sinus tarsi approach, have gained popularity given their lower rates of wound complications. Reported wound complications after the sinus tarsi approach range from 3% to 13%.^{1,12,18,20} Here we report 0% major and 14% minor wound complication rates, consistent with the rates reported in the literature.

There is conflicting literature on the rate of hardware removal after operative fixation of the calcaneus through the sinus tarsi approach vs extensile lateral approach. Weber et al²⁷ found the rate of hardware removal to be 42% in the sinus tarsi group and 12% in the extensile lateral group. Conversely, Kline et al¹⁹ found a rate of 3% hardware removal in the sinus tarsi group and 7.6% in the extensile approach. Another study noted a 49% rate of hardware removal after fixation of calcaneus via sinus tarsi approach.⁷ In our cohort, two of 22 patients (9.1%) required removal of painful hardware, consistent with the lower end of rates reported in the literature.

This study is not without limitations. First, there is a relatively small sample size that leads to difficulty assessing for statistical relationships between radiographic parameters and functional outcome scores. Specific selection criteria for this approach was not clearly delineated—limiting the generalizability of the study. Although we did identify a series of 22 calcaneus fractures that underwent operative fixation through a sinus tarsi approach, this study is likely underpowered to draw statistically significant conclusions. This study received industry support, which in theory could introduce bias. However, the patients received no monetary compensation and objective radiographic data were measured by 2 authors without industry relationships. Therefore, we believe that bias was limited. In addition, with follow-up of 1 year postoperation, it is possible we did not identify patients who later went on to develop symptomatic subtalar arthritis.

In conclusion, this study demonstrates that in select calcaneal fractures, excellent anatomic alignment can be achieved through the sinus tarsi approach with low rates of

wound complications and good patient-reported outcomes. We would encourage future studies to further investigate these findings in a parallel patient population.

Ethical Approval

Ethical approval for this study was obtained from Atrium Health Institutional Review Board, protocol no. 9074.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: from Acumed (funded current study). ICMJE forms for all authors are available online.

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